EFFECT OF ADDING SPIRAL REINFORCING TO VERTICALLY REINFORCED CONCRETE COLUMNS

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THE EFFECT OF ADDING SPIRAL

REINFORCING TO VERTICALLY REINFORCED CONCRETE COLUMNS.

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The Effect of Adding Spiral Reinforcing to Longitudinally Reinforced Columns.

Introduction

The purpose of these tests was to study the effect of adding spiral steel to longitudinally reinforced columns. Two columns were tested, one with vertical reinforced steel, and the other reinforced with spiral and vertical steel. Both columns were made with a protective shell an inch thick on the outside of the steel. While this made it difficult to study the distribution of stress in the concrete and reinforcing steel, usefull information was obtained in regard to the behavior of this shell. The work on columns was done in the mechanical laboratory, the vertical reinforced column being made inside and the other or spiral, outside. The cement, sand and stone tests were made in the cement laboratory and the different strength tests made in the laboratory of the main building.

Materials

Materials.

Cement:- Chicago portland cement from the local market was used in the tests. Table I gives the tensile strength of neat and 1:3 mortar briquettes tested at 7 and 28 days.

Table I

Briquettes Number	Ultimate strength, lbs/in^2			
	Age 7 days		Age 28 days	
	Neat	1:3 Mortar	Neat	1:3 Mortar
1	430#	340#	777#	450#
2	456#	319#	703#	425#
Average	443#	329.5#	740#	437.5#

Sieve Analysis of Cement.

200 grams of dried cement, taken from four bags and thoroughly mixed, were placed in the testing sieve agitator and operated for ten minutes, the following results being obtained,

Table II

# of sieve	grams retained	% retained
10	0	
20	0	
30	0	
40	.10	.051
50	2.15	1.100
60	.96	.491
80	12.57	6.42
100	13.40	6.85
200	61.30	31.350
Passing all	106.35	54.300
Total	195.83	100.9[illegible]1

Sand:- The sand used was a good torpedo obtained from the local market. The mechanical analysis of this sand is ootained in table III, a 500 gram sample being used.

Taole III

Analysis of Sand

Per cent Voids 30	Weight per cu. ft. = 101.6#	
Sieve meshes per in.	grams retained	% retained
10	165.30	33.50
20	95.10	19.25
30	84.10	17.00
40	60.60	12.25
50	61.10	12.38
60	12.45	2.52
80	7.65	1.55
100	3.00	.61
200	2.00	.40
Passing all	2.60	.53
Total	493.90	99.99 %

Voids in sand (by means of graduate method)

Trial #I Volume of water ------------------ 60 cc.

Volume of saturated mixture------- 195 cc.

% of voids ------------- $\frac{60}{195}$ X 100 = 30%

Trial #2 Volume of water-------------------- 60 cc.

Volume of saturated mixture------- 200 cc.

% of voids--------------- $\frac{60}{200}$ X 100=30.+ %

Value of 30% used

Stone:- A soft crushed limestone was used, the voids of which were found by the pail method.

Weight of pail empty ----------------- 19.72#

" " " plus water------------- 56.02
Difference---------------------------- 36.30#

Volume of pail $\frac{36.30}{625} = 58.08$ cubic feet.

Weight of pail plus crushed stone------69.21#

" " " " " " & water86.62#
Weight of water----------------------- 17.41#

% of voids $\frac{17.41}{36.30} \times 100 = 47.96$ % or 48 %

Concrete:- Computations for percentage of ingredients.

Voids in stone ------------------------ 48 %

" " sand -------------------------- 30 %

40% excess of mortar over the voids in the stone used.

Cement paste has 0.8 the volume of dry cement.

Begin with 100 parts of crushed stone.

No. of parts of mortar $.48 \times 100 \times 1.4 = 67.2$ parts

Mortar = sand plus cement.

$$67.2 = S(1 - .3) + \frac{S(.30) \times 1.2}{.8}$$

$$53.76 = .528S + .36S = .888\ S$$

$$S = \frac{53.76}{.888} = 60.5 \text{ parts of sand.}$$

$$\frac{60.5 \times .3 \times 1.2}{.8} = 27.2 \text{ parts of cement.}$$

	Cement		Sand		Crushed Stone
Parts	27.2	:	60.5	:	100
	1	:	2.22	:	3.68

Computation of Weights of Ingredients.

Weight of cylinders assumed ---------------- 100# each.

Volume of column $= \frac{11^2 \times .7854 \times 10}{144} = 6.6$ cu. ft.

Weight of column $= 6.6 \times 150 = 990$ lbs.

1200 pounds of concrete made up in three batches.

Weight of cement per cubic foot ----------- 97# (say 95# net)

" " stone " " " ----------- 93.6

" " sand " " ---------- 101.6

	Cement	Sand	Stone
By vol.	1 ———	2.22 ———	3.68
Wt. relative) to cement wt)	$\frac{95}{95} = 1$ ———	$\frac{101.6}{95} = 1.07$ ———	$\frac{93.6}{95} = .985$
Therefore by) weight)	1 ———	$1.07 \times 2.22 = 2.37$ —	$.985 \times 3.68 = 3.62$

Proportions for 400# Batch.

Cement------------ 1

Sand ------------ 2.37

C. S. ------------ 3.62

6.99 or 7 parts.

Cement $\frac{400}{7} =$ ----------- 57.1#

Sand $2.37 \times 57.1 =$ --- 135.0

Stone $3.62 \times 57.1 =$ --- 208.0

400.1 lbs of concrete.

In mixing each batch the sand was first spread on the mixing platform and the cement added evenly on top. The sand and cement were thoroughly mixid while dry and then water added to make a good plaster paste. The stone was added after the mortar had been mixed for ten minutes and additional water used to make a good wet concrete which would flow readily around the reinforcing without much puddling. The way in which the water was added played an important part in securing a uniform consistency throughout the batch. The cement was carried to the form in pails, a platform being erected to facilitate the handling of same.

Steel:- The vertical steel used was a mild steel, while the steel in the spiral was a high carbon. The former was $\frac{1}{2}$" diameter and the diameter of the latter was .1761", the pitch of the spiral being 1" and rigidly held by spacing bars. Two inch pieces of the vertical steel were tested for compression and 4" pieces of the spiral steel were tested for tension. Table IV gives the mechanical analysis for the two steels.

Length of bar	Area in sq. in.	Load at yield pnt.	Max. load lbs.	Stresses at yield pnt. lbs./in.^{2}	Ultimate strength lbs/sq. in.
Compression 2"	.1975	8400	9,700	42,500	49,250
" 2	.2235	8530	11,400	38,200	51,000
" 2	.1958	8400	12,500	42,850	63,800
Tension 4	.025	1700	2500	69,800	102,600

Specimens.

Making, Curing and Testing.

III Specimens:- Making, Curing and Testing.

Auxiliary Specimens.

From the first two batches of concrete mixed for each column, a 7" cylinder was made. Tests of these cylinders served to indicate the strength of the concrete used in the columns. The cylinders were left under the same conditions as the columns and those made at the time the column was, were tested the same day as the column. (34 days)

Compressive Strength of Concrete Cylinders				
Column	Specimens 7" x 16" cylinders	Age in days	Modulus of Elasticity	Ultimate strength lbs/sq. in.
1	1	34		860
1	2	34		1110
2	3	34	1,940,000	2127.9

Columns.

Forms:- The forms were made octagonal, of 2" stock 10' long and beveled to form an octagonal cylinder. The eight pieces were held together by 2" x 4" timbers bolted together. These were put around the form as shown in fig. I and wedges put in to make the form as tight as possible. The bottom was nailed to the form

and small pieces of wood for spacing the vertical rods placed. About 6" from the bottom a wedge shaped hole was cut to enable the observer to set the rods on the small wood blocks. A scaffold was built around the form and the latter rigidly fastened to it. The steel rods for the vertical reinforcing were held in place by iron hoops 1/8" x 3/8" in cross section, spaced every 6" of length. In the spiral reinforcing the vertical rods were fastened to the spiral directly, hay wire being used and ties made every 6".

Making:- In fabricating the two columns, the concrete was poured in from a pail at the top. While the column was being poured it was continually puddled, both inside and outside of the reinforcing to prevent the formation of pockets and blow holes. A day or two after the columns were made, a thin coat of 1:1 mortar was applied to their top. In making the column with the spiral reinforcing, considerable difficulty was encountered in keeping the steel in the center of the form.

Curing:- The forms were removed from the columns at the end of seven days and then they were allowed to cure in the open air for 27 days.

Testing:- After 28 days, the columns were tested in the 400,000 pound Olsen testing machine in the laboratory. The column was put in the machine and bedded on a cast iron plate at the top and bottom, sheets of paper being placed between the column and the plates to fill up any depressions in the surface. The column was loaded in increments of 10,000 pounds. The cylinders were tested in a 200,000 pound Riehle testing machine, increments of 2000 pounds being used.

Measurements of the longitudinal deformation were made by means of compressometers, which measured to 0.0001 of an inch. The compressometers shown in fig. IIIa and IIIb were used, the former for deformations of the cylinders and the latter for deformations of the columns. For use on the columns, four bars were fastened on the column about three feet from the top. On opposite sides of the column brass rods were fastened to the bars and insulated by means of fibre. The other end of the rods formed a contact for a dial fastened on another set of bars spaced 44 inches below the first set. The instrument has a vertical scale divided into tenths of an inch and these in turn are divided into four equal

parts, making each vertical division equal to 1/40 of an inch. The wheel or dial, worked by a vertical screw was divided into 250 equal parts and one turn of it corresponded to one division on the vertical scale, or 1/40 of an inch, making each division on the wheel equal to 0.0001 of an inch. Contact was assured by means of a bell in circuit with a storage battery, After each load was applied, the dial on one side was read and recorded, then the dial on the other side.

To measure the deformation of the spiral, the shell was taken off near the center for about a foot, exposing the spiral steel. One end of a steel tape was soldered to the spiral and wound around five times, the other end being held taut by means of a spring. A transit was used to read the deformations, but the spiral did not undergo any change until the last two loads were applied, so that the values were not considered trustworthy and will not be reported.

Experimental Results and Discussion.

Discussion.

I Tests of 7" Cylinders.

Log sheet III contains the result of compression tests made on the seven inch cylinders. Owing to misunderstanding, two of the cylinders were tested for ultimate strength only, and did not show as strong as the last one tested which gave an average modulus of elasticity of 1,940,000 lbs./sq. in., and an ultimate strength of 2127 lbs./sq. in. The last cylinder tested seemed to be abnormally strong in comparison with the others, being almost twice as great in ultimate strength as the next highest. This variation being due to a great extent to the fact that the load was given a rest of a few minutes to give time to read the compressometer whereas in the other the load was applied until rupture occurred. The break in the cylinders was diagonal, running from top to bottom.

II Test of Longitudinally Reinforced Column.

When tested, the column showed itself to be very stiff for a load about 2/3 of its ultimate strength, when the shell began to peel at the bottom, which together with the deformations indicated that the yield

point of the steel had been reached. At this point, however, owing to the insufficient support offered by the widely separated bands, it began to fail. The re-inforcement failed by buckling as shown in fig. II, while the concrete failed in the same way as it did for the cylinders, that is, diagonally. The data for this column is contained in log sheet I.

Test of Column with Longitudinal and Spiral Reinforcing.

This column showed a very marked increase in stiff-ness over the preceding column, the deformation for the same load being about one third to one half that of the column, with just the longitudinal reinforcing. At half load, the column began to spall at the top, but this was due to the concave surface which had been filled with Plaster of Paris, making the edges brittle. At 7/8 of the ultimate load, the column began to spall at the bot-tom, and failed at 310,000 lbs. by the breaking of the first hoop at the top. As the load was kept on the column, the first five spirals at the top gave way in the following fifteen minutes and the protecting shell began to spall near the center.

Conclusions.

Conclusions.

1. The plain concrete cylinder had an average modulus of elasticity of 1,940,000 lbs./in.^{2} and an ultimate strength per sq. in. of 2137 pounds. Although the cylinder showed up exceptionally strong under practical working conditions, the liability of variations in strength and eccentricity make the use of a low working stress necessary for such a brittle material.

2. The vertical reinforcing in the first column did not seem to aid the strength of the column at all. In fact the ultimate strength was below that of the plane concrete cylinder.

3. The double reinforcing, spiral and vertical, was the only one that seemed to effect the strength of the column. The deformations were small in comparison to the first column, and although the shell peeled off at a load of 2036 pounds/sq. in., the column continued to hold up a load twice as great or 4194 lbs./in.^{2}

4. The spiral reinforcing kept the vertical reinforcing from bulging. The latter added to the stiffening of the column until the yield point was reached, when the stress was taken up by the spiral reinforcing.

The spiral reinforcing did not show any deformation until 7/8 of the ultimate load was applied, which tended to show that the concrete was dense and compact.

5. The concrete was free from air pockets and blow holes, and in rupturing, the stones were sheared off clean, showing a good compact and dense mixture with a good bond. From the results obtained, the conclusions can be drawn that the longitudinal reinforcing is of no aid in the strengthening of columns outside of adding to the stiffness, whereas the addition of spiral reinforcing more than doubled the strength of the former, and as the ultimate strength was twice that at the time of spalling, it shows that the failure was slow in comparison to the vertical reinforced column.

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Log Sheets.

#I Log sheet for longitudinal reinforced concrete column.

Original diameter - 10"

Original area - 78.54 sq. in.

Length under measurement - 44".

Length of column - 10'-)".

Load		Compressometer Readings			Compression		Modulus of Elasticity
Actual P	Per sq in P	L.	R.	Mean	Actual	Per in.	$E=\frac{P}{e}$
0	0	.4422	.2911	.3562	0	0	0
10000	127.3	.4454	.2928	.3641	.0079	.00018	707250
20000	254.6	.4488	.2945	.3717	.0155	.00035	727400
30000	381.9	.4520	.2963	.3742	.0180	.00041	939000
40000	509.2	.4560	.2961	.3761	.0199	.00045	1132000
50000	636.5	.4596	.2972	.3784	.0222	.00050	1273000
60000	763.8	.4623	.2955	.3789	.0227	.00052	1468000
70000	891.1	.4665	.2953	.3809	.0247	.00056	1590000
80000	1018.4	.4692	.2954	.3823	.0261	.00059	1726000
90000	1145.7	.4751	.2955	.3853	.0291	.00066	1736000
100000	1273.0	.4815	.2955	.3885	.0323	.00074	1707000
110000	1400.3	.4888	.2956	.3923	.0360	.00082	1707000
120000	1527.6	.4950	.2946	.3948	.0386	.00088	1736000
130000	1654.9	.5038	.2945	.3992	.0430	.00098	1687000
140000	1782.2	.5137	.2962	.4050	.0488	.00110	1782000
149200	1896.8	——	——		——		
						Average	1420900

#II Log sheet for spiral and longitudinal reinforced concrete columns

Original diameter - 10"

Original area - 78.54 sq. in.

Length under measurement 44".

Length of column 10' - 0"

	Load		Compressometer Readings			Compression		Modulus of Elasticity
Spiral Expansion	Actual P	Per sq in. P	L.	R.	Mean	Actual	Per in.	$E=\frac{P}{e}$
0	0	0	-	-	-	-	-	-
0	10000	254.6	.1495	.1898	.1697	-	-	-
0	20000	381.9	.1502	.1906	.1704	.0007	.000016	23870000
0	30000	560.1	.1514	.1922	.1718	.0021	.000048	11670000
0	44000	763.8	.1530	.1935	.1733	.0036	.000081	7858000
0	50000	891.1	.1548	.1950	.1749	.0051	.000116	6584000
0	60000	1018.4	.1564	.1968	.1766	.0069	.000157	5680000
0	70000	1145.7	.1581	.1978	.1780	.0083	.000189	5390000
0	80000	1273.0	.1597	.1985	.1791	.0094	.000214	5353000
0	90000	1400.3	.1616	.2005	.1811	.0114	.000260	4890000
0	100000	1527.6	.1634	.2021	.1828	.0131	.000300	4668000
0	110000	1654.9	.1655	.2035	.1845	.0148	.000338	4520000
0	120000	1782.2	.1662	.2056	.1859	.0152	.000345	4780000
0	130000	1909.5	.1687	.2080	.1884	.0187	.000425	4180000
0	140000	2036.8	.1702	.2085	.1892	.0195	.000443	4310000
0	150000	2164.1	.1727	.2128	.1928	.0231	.000525	3870000
0	160000	2291.4	.1745	.2145	.1945	.0248	.000564	3836000
0	170000	2418.7	.1775	.2160	.1968	.0271	.000620	3690000
0	180000	2546.0	.1805	.2173	.1989	.0292	.000664	3640000
0	190000	2673.3	.1830	.2192	.2011	.0314	.000714	3564000
0	200000	2800.6	.1863	.2220	.2042	.0345	.000784	3410000
0	210000	2927.9	.1907	.2253	.2080	.0383	.000870	3318000
0	220000	3055.2	.1958	.2285	.2122	.0425	.000966	3030000
0	230000	3182.5	.1995	.2308	.2152	.0455	.001034	2950000
0	240000	3349.8	.2030	.2335	.2183	.0486	.001105	2880000
0	250000	3437.1	.2089	.2383	.2236	.0539	.001225	2734000
0	260000	3564.4	.2210	.2387	.2299	.0602	.001370	2510000
0	270000	3691.7	.2335	.2427	.2381	.0684	.001556	2280000
5	280000	3819.0	.2558	.2470	.2514	.0817	.001860	1980000
4	290000	4193.8	.2835	.2447	.2641	.0944	.002145	1780000
7	300000							
11	310800							

#III Log sheet for 7" concrete cylinder

Original diameter - 7"

Original area - 38.48 sq. in.

Length under measurement - 12"

Length of cylinder - $16\frac{1}{4}$"

Load		Compressometer Readings in inches			Compression in inches		Modulus of Elasticity
Actual P	Per Sq In. p	L.	R.	Mean	Actual	Per In.	$E=\frac{p}{e}$
0	0	.7900	.5000	.6450	0	0	
1200	31.1	.7900	.5000	.6450	0	0	
2000	51.9	.7902	.5003	.64525	.00025	.00002	2595000
4000	103.8	.7902	.5006	.6454	.0004	.000033	3120000
6000	155.7	.7900	.5022	.6461	.0011	.000091	1715000
8000	207.6	.7904	.5029	.64665	.00165	.000137	1510000
10000	259.5	.7903	.5031	.6467	.0017	.00014	1850000
12000	311.4	.7902	.5035	.64685	.00185	.00015	2070000
14000	363.3	.7898	.5040	.6469	.0019	.00016	2270000
16000	415.2	.7896	.5048	.6472	.0022	.00018	2300000
18000	467.1	.7897	.5064	.64805	.00305	.00025	1870000
20000	519.0	.7899	.5078	.64885	.00385	.00032	1620000
22000	570.9	.7905	.5090	.64975	.00475	.00039	1465000
24000	622.8	.7905	.5090	.64975	.00475	.00039	1595000
26000	674.7	.7915	.5087	.6501	.00501	.00042	1605000
28000	726.6	.7913	.5113	.6513	.00630	.00052	1395000
30000	778.5	.7924	.5104	.6514	.0064	.00053	1465000
32000	830.4	.7912	.5108	.6510	.0060	.00050	1660000
34000	882.3	.7928	.5107	.65175	.00675	.00054	1635000
36000	934.2	.7885	.5117	.6501	.0051	.00042	2220000
38000	986.1	.7882	.5119	.65005	.00505	.00042	2345000
40000	1038.0	.7880	.5123	.65015	.00515	.00042	2450000
42000	1089.9	.7880	.5133	.65065	.00565	.00047	2320000
44000	1141.8	.7880	.5138	.6509	.0059	.00049	2330000
46000	1193.7	.7877	.5145	.6511	.0061	.00051	2340000
48000	1245.6	.7880	.5157	.65185	.00685	.00057	2180000
50000	1297.5	.7872	.5178	.6525	.0075	.00062	2090000
52000	1349.4	.7870	.5186	.6528	.0078	.00065	2075000
54000	1401.3	.7878	.5210	.6544	.0094	.00078	1795000
56000	1453.2	.7872	.5208	.6540	.0090	.00075	1935000
58000	1505.1	.7870	.5212	.6541	.0091	.00076	1980000
60000	1557.0	.7872	.5220	.6546	.0096	.00080	1945000
62000	1608.9	.7858	.5224	.6541	.0091	.00076	2180000
64000	1660.8	.7857	.5240	.65485	.00985	.00082	2025000
66000	1712.7	.7854	.5253	.65535	.01035	.00086	1995000
68000	1764.6	.7845	.5274	.65595	.01095	.00091	1935000
70000	1816.5	.7830	.5290	.6560	.0116	.00096	1890000
72000	1868.4	.7823	.5316	.65695	.01195	.00099	1873000
74000	1920.3	.7820	.5352	.6586	.0136	.00113	1685000
76000	1972.2	.7815	.5366	.65905	.01405	.00117	1675000
78000	2024.1	.7802	.5396	.6599	.0149	.00124	1620000
80000	2076.0						
82000	2127.9					Average	1940000

#IV Log sheet for Spiral Reinforcing

Original Average Diameter - .1761"

Original Average Area - .024355 sq. in.

Length under measurement - 4"

Load		Extensometer Readings			Extension		Modulus of Elasticity
Actual	Per Sq In.	L.	R.	Mean	Actual	Per In.	$E \frac{P}{e}$
150	6170	.0043	.0063	.0053	.0008	.00010	61700000
400	20520	.0067	.0097	.0082	.0037	.00046	44600000
600	24640	.0090	.0124	.0107	.0062	.00077	32000000
800	32880	.0108	.0150	.0129	.0084	.00105	31300000
1000	41080	.0129	.0177	.0153	.0108	.00135	30400000
1200	49280	.0152	.0200	.0176	.0131	.00164	30000000
1400	57600	.0182	.0224	.0203	.0158	.00198	29100000
1500	61600	.0194	.0253	.0214	.0169	.00211	29200000
1600	65800	.0210	.0248	.0230	.0185	.00231	28500000
1700	69800	.0230	.0277	.0253	.0208	.00260	26800000
1800	74000	.0247	.0280	.0263	.0218	.00272	27200000
1900	78000	.0277	.0314	.0295	.0250	.00312	25000000
2000	82200	.0294	.0333	.0313	.0268	.00335	24500000
2100	86400	.0328	.0372	.0350	.0305	.00381	22700000
2200	90400	.0369	.0422	.0395	.0350	.00438	20600000
2300	94400	.0430	.0480	.0455	.0410	.00512	18400000
2400	98800	.0514	.0560	.0537	.0492	.00615	16050000
2420	99600	.0545	.0660	.0602	.0557	.00696	14300000
2500	102600						
	Ultimate Strength 102,600 lbs. per sq. in.						

#V Log Sheet for Vertical Reinforcing, Sample No. I.

Original Average Diameter - .50145"

Original Average Area - .19745 sq. in.

Length under Measurement - 2"

Load		Compressometer			Compression		Modulus of Elasticity
Actual P	Per Sq In. p	L.	R.	Mean	Actual	Per In. e	$E = \frac{p}{e}$
0	0	2.0555	2.0570	2.0562	0	0	
600	3040	.0551	.0570	.0561	.0001	.000049	60800000(?)
2600	13200	.0545	.0560	.0552	.0010	.000490	26900000
3750	19000	.0542	.0552	.0547	.0015	.000732	26000000
4850	24600	.0540	.0549	.0545	.0017	.000830	29600000
5700	29000	.0539	.0543	.0541	.0021	.001025	28300000
6430	32600	.0535	.0541	.0538	.0024	.001170	27800000
7050	35800	.0531	.0540	.0535	.0027	.001320	27100000
7600	38600	.0530	.0539	.0535	.0027	.001320	29200000
7950	40300	.0529	.0539	.0534	.0028	.001370	29400000
8320	42200	.0499	.0523	.0510	.0052	.002540	16600000
8500	43100	.0488	.0509	.0498	.0064	.003120	13800000
8400	42500	.0475					
8500	43100	.0460	.0460	.0460	.0102	.004930	8730000
8450	42750	.0447	.0432	.0454	.0108	.005270	8120000
8400	42500	.0428	.0398	.0443	.0119	.005810	7310000
8430	42700	.0390	.0351	.0371	.0191	.009320	4575000
8450	42750	.0311	.0289	.0300	.0262	.012800	3340000
8450	43300	.0202	.0160	.0181	.0381	.018600	2320000
8650	43800	.0080					
Compressometer Removed					Divider Readings		
8650	43900		1.9520		.048	.0240	1830000
8950	45500		1.951		.049	.0245	1860000
9300	47250		1.925		.075	.0375	1260000
9700	49250	Failure by bending					
		Ultimate Strength 49,250 lbs. per sq. in.					

#VI Log Sheet for Vertical Reinforcing, Sample No. II

Original Average Diameter - .4986"

Original Average Area - .2235 sq. in.

Length under Measurement - 2"

Load		Compressometer			Compression		Modulus of Elasticity
Actual P	Per Sq In. P	L.	R.	Mean	Actual	Per In.	$E=\frac{P}{e}$
50		2.0615	2.0671	2.0643			
600	2685	.0616	.0669	.0642	.0001	.000048	56000000
1050	4700	.0615	.0668	.0641	.0002	.000096	49000000
1900	8500	.0614	.0660	.0637	.0006	.000288	29500000
3300	14800	.0610	.0650	.0630	.0013	.000630	23500000
4450	19900	.0608	.0647	.0627	.0016	.000775	25700000
5450	24400	.0604	.0640	.0622	.0021	.001020	23900000
6300	28200	.0601	.0640	.0620	.0023	.001115	25300000
7250	32400	.0600	.0639	.0620	.0023	.001115	29100000
7650	34200	.0592	.0639	.0616	.0027	.001310	26100000
7750	34700	.0590	.0639	.0614	.0029	.001405	24700000
8100	36200	.0588	,0634	.0611	.0032	.001550	23400000
8350	37400	.0584	.0625	.0604	.0039	.001890	19800000
8530	38200	.0576	.0600	.0588	.0055	.002665	14300000
8650	38700	.0560	.0558	.0559	.0084	.004070	9510000
8350	37400	.0560	.0558	.0559	.0084	.004070	9200000
8600	38400	.0542	.0525	.0533	.0110	.005330	7200000
8350	37400	.0541	.0525	.0533	.0110	.005330	7025000
8530	38200	.0511	.0482	.0496	.0147	.007120	5370000
8350	37400	.0511	.0482	.0496	.0147	.007120	5260000
8580	38400	.0470	.0435	.0452	.0191	.009250	4160000
8350	37400	.0469	.0432	.0450	.0193	.009340	4000000
8700	38900	.0390	.0349	.0369	.0274	.013300	2930000
8350	37400	.0388	.0347	.0367	.0276	.013380	2800000
8650	38700	.0300	.0252	.0276	.0367	.017780	2180000
8350	37400	.0297	.0251	.0274	.0369	.017850	2100000
8750	39200	.0184	.0144	.0164	.0479	.023200	1690000
	Divider Readings between original 2 points						
8750	39600	1.97			.03	.015	2640000
8980	39900	1.95			.05	.025	1600000
11400	51000						
		Ultimate Strength 51,000 lbs. per sq. in.					

#VII Log sheet for Vertical Reinforcing, Sample No. 3.

Original Average Diameter - .4993"

Original Average Area - .1958 sq. in.

Length under measurement - 2" .

Load		Compressometer			Compression		Modulus of Elasticity
Actual P	Per sq in p	L.	R.	Mean	Actual	Per in.	$E = \frac{p}{e}$
180		2.0638	2.0580	2.0609	.0000		
890	4550	.0638	.0576	.0607	.0002	.000097	46900000
2300	11750	.0637	.0566	.0601	.0008	.000388	30300000
3500	17880	.0635	.0560	.0597	.0012	.000582	30700000
4600	23450	.0630	.0558	.0594	.0015	.000727	32300000
5400	27600	.0628	.0555	.0591	.0018	.000872	31700000
6170	31500	.0624	.0540	.0582	.0027	.001310	24000000
7050	36000	.0619	.0505	.0562	.0047	.002280	15800000
7350	37600	.0618	.0490	.0554	.0055	.002670	14100000
7800	39800	.0611	.0465	.0538	.0071	.003440	11580000
8150	41650	.0600	.0419	.0509	.0100	.004850	8600000
8300	42400	.0550	.0355	.0452	.0157	.007610	5580000
8200	41850	.0528	.0323	.0425	.0184	.008920	4700000
8400	42850	.0450	.0280	.0365	.0244	.011840	3620000
8300	42350	.0465	.0245	.0355	.0245	.012320	3440000
8380	42750	.0410	.0240	.0325	.0284	.013800	3095000
8400	42850	.0350	.0187	.0268	.0341	.016540	2590000
8420	43000	.0285	.0127	.0206	.0403	.019550	2200000
8700	44400	.0224	.0067	.0145	.0464	.022500	1975000
8900	45500	.0190	.0027	.0108	.0501	.024300	1870000
Extensometer Removed							
12500	63800	Maximum					
Ultimate Strength 45,500 lbs. per sq. in.							

Curves

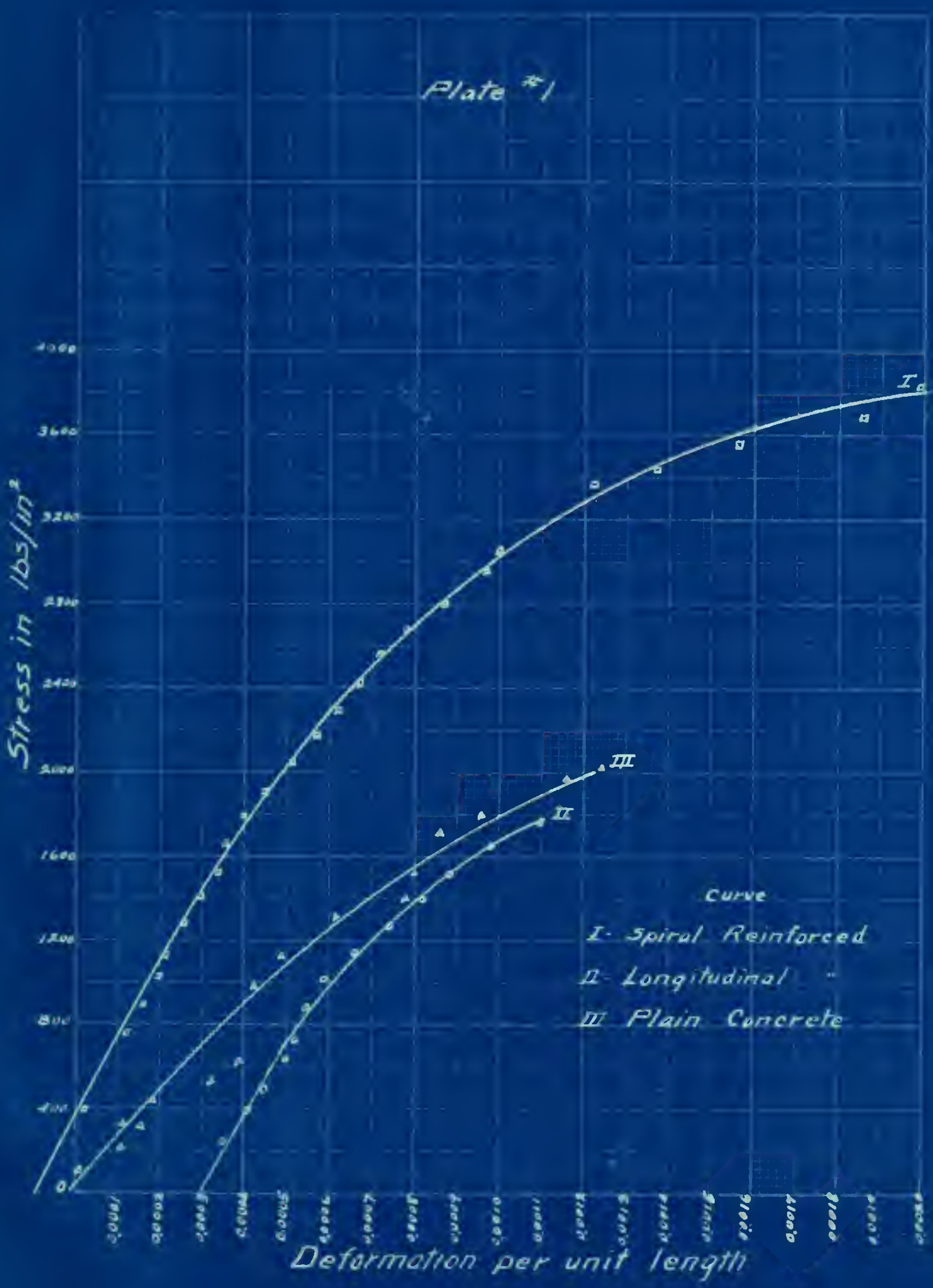
Plate #1
Stress in lbs/in²
Deformation per unit length
Curve
I- Spiral Reinforced
II- Longitudinal "
III Plain Concrete
I
II
III

215

7x9

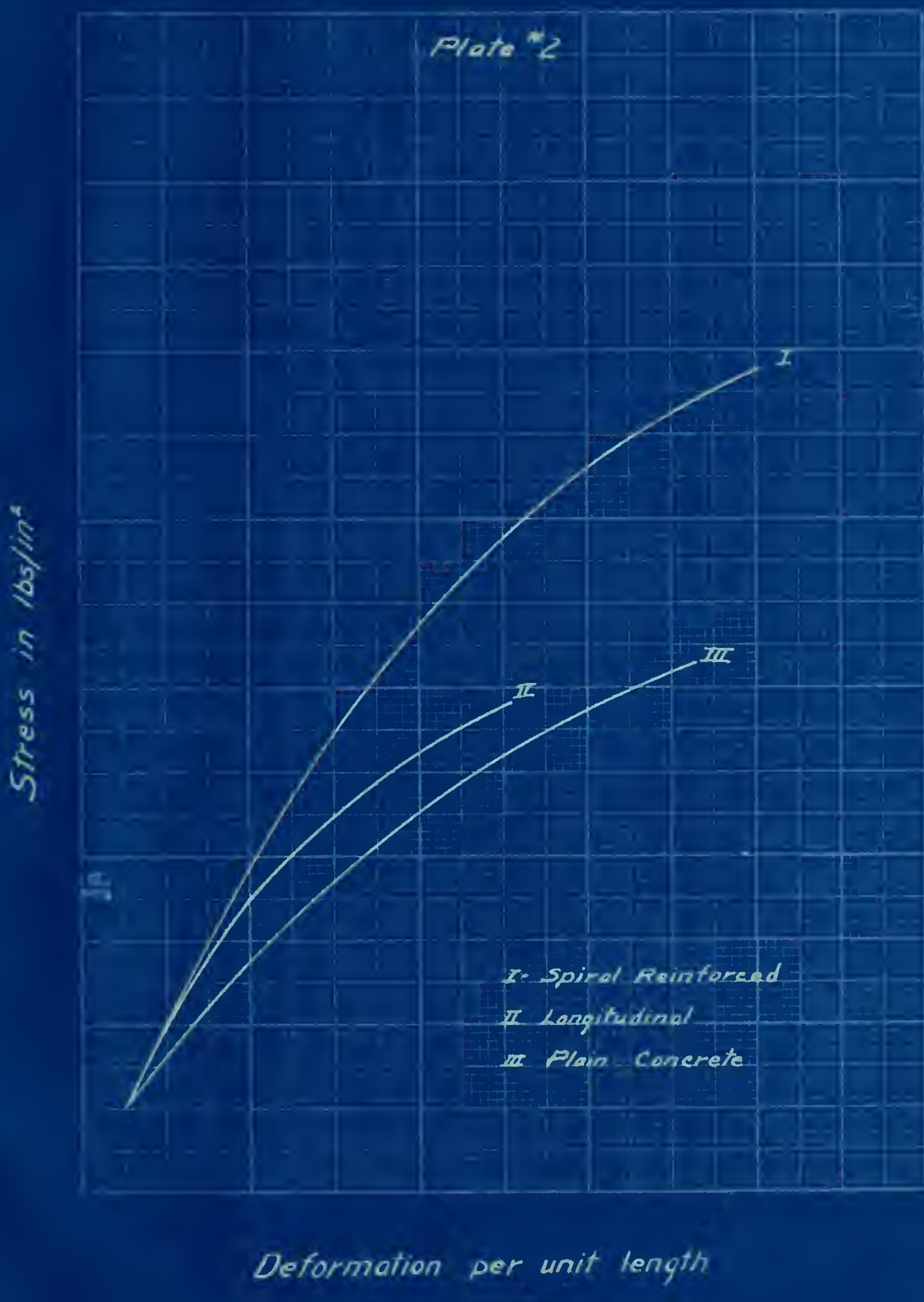
Plate #2
Stress in lbs/in²
I
II
III
I- Spiral Reinforced
II Longitudinal
III Plain Concrete
Deformation per unit length

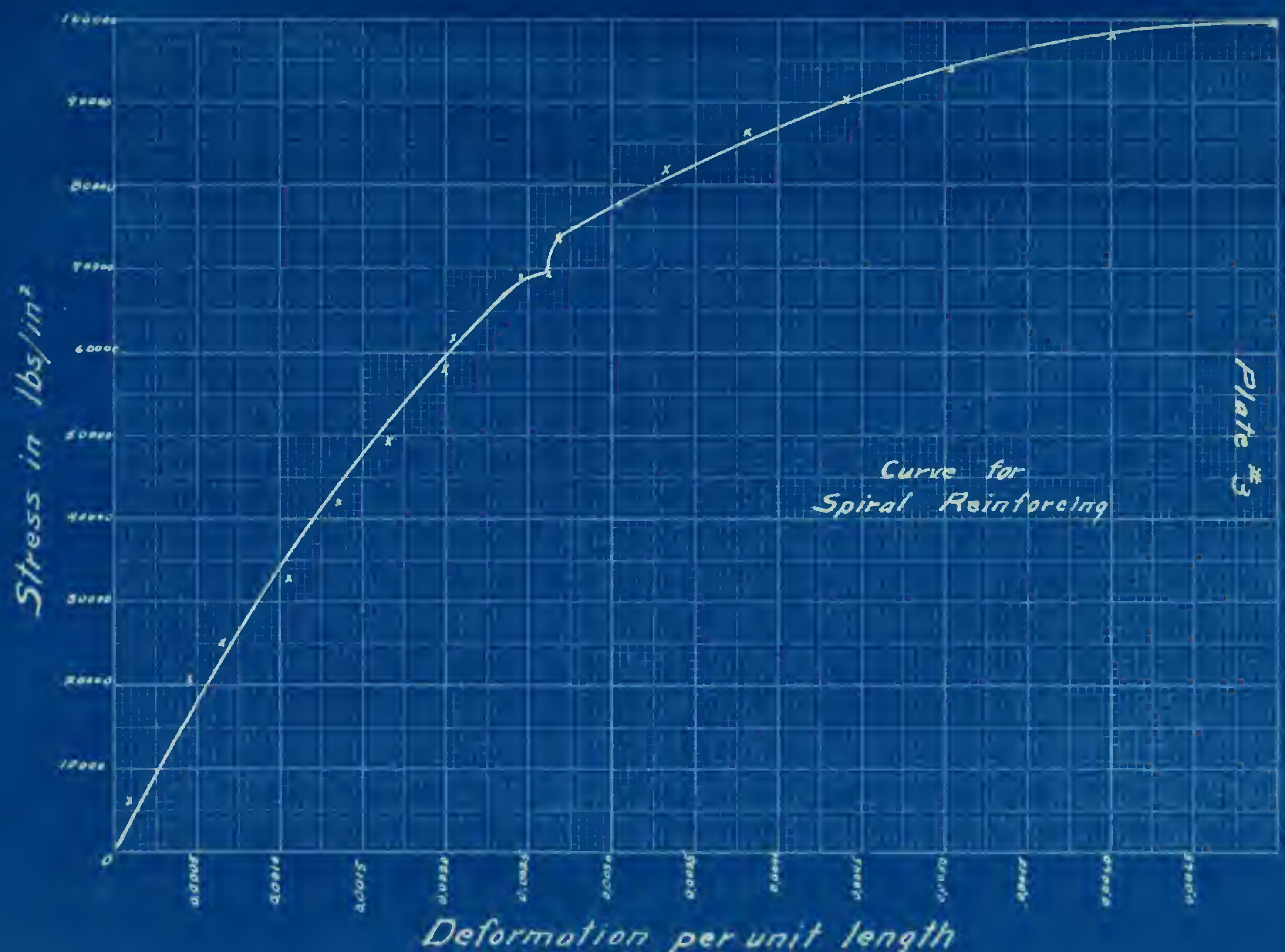
Plate #3
Curve for
Spiral Reinforcing
Stress in lbs/in²
Deformation per unit length

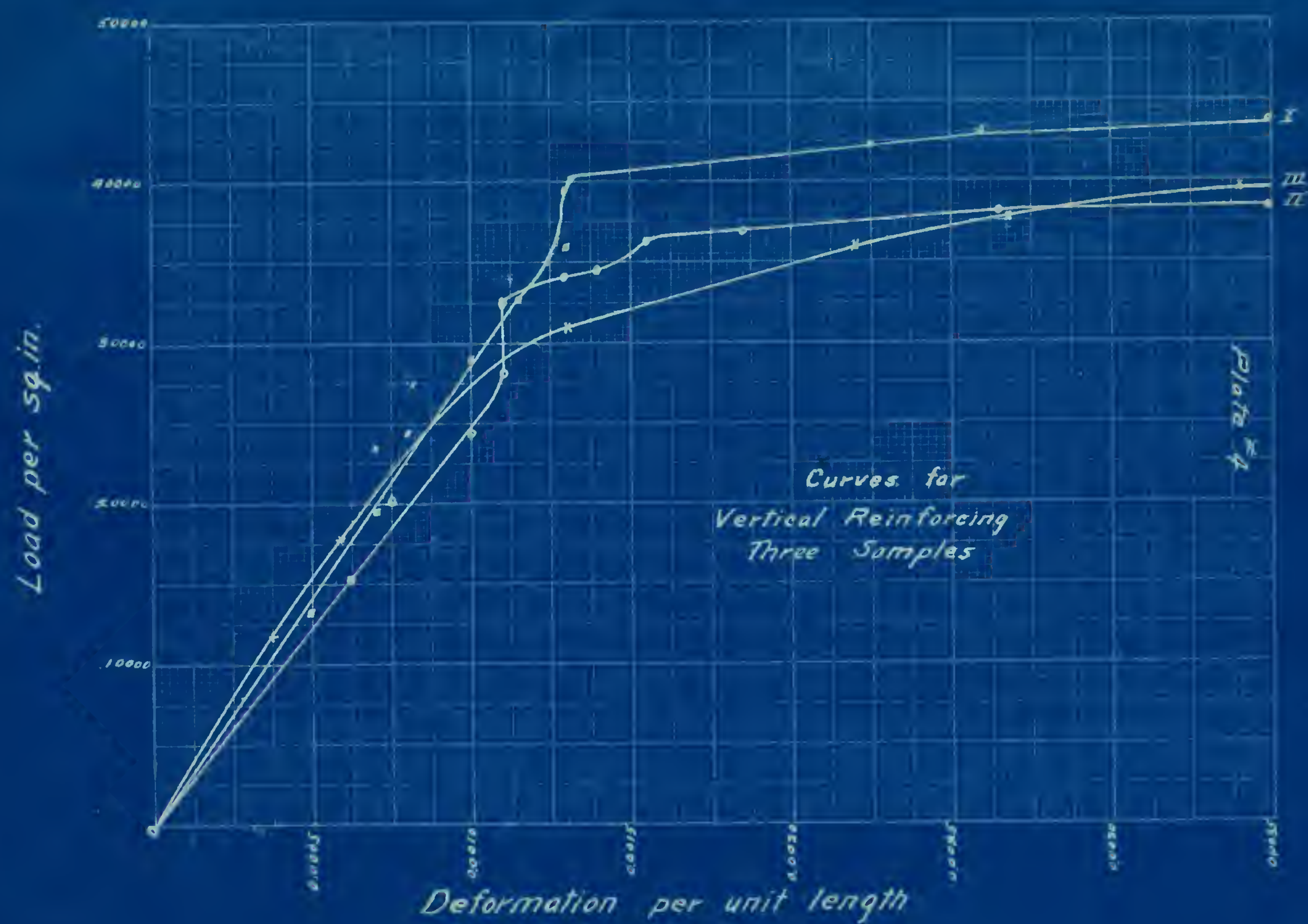
Plate #4
Curves for
Vertical Reinforcing
Three Samples
I
II
III
50000
40000
30000
20000
10000
0.0005
0.0010
0.0015
0.0020
0.0025
0.0030
0.0035
Load per sq. in.
Deformation per unit length

Illustrations

Fig. 1

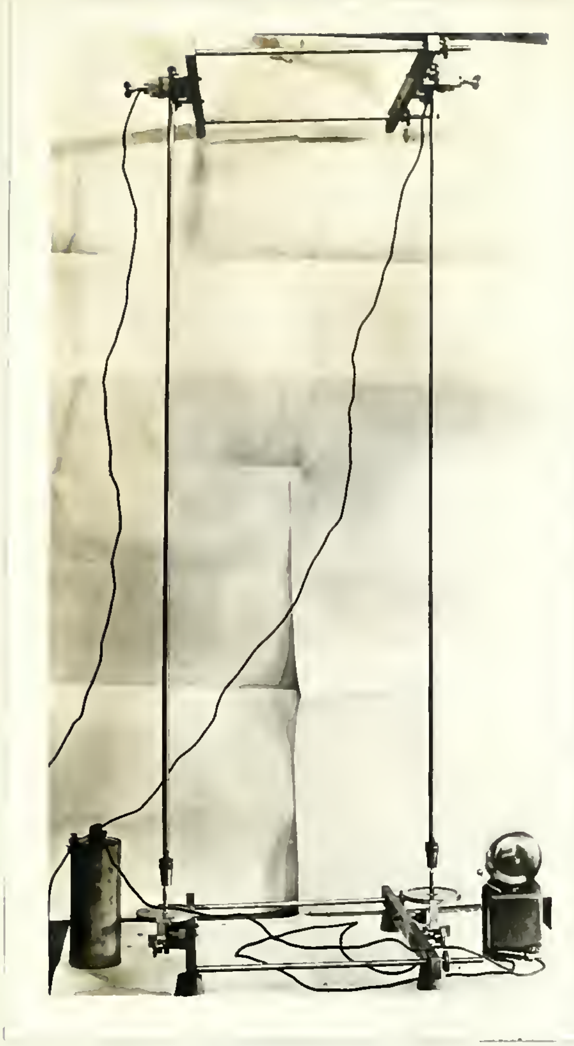

Fig. 3b

Fig. 3a

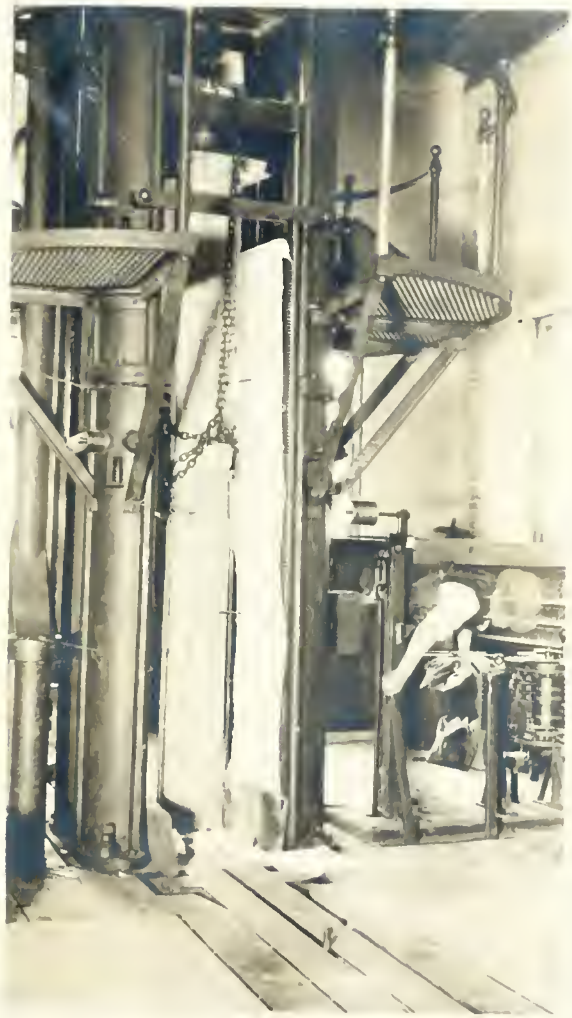

Fig. 4

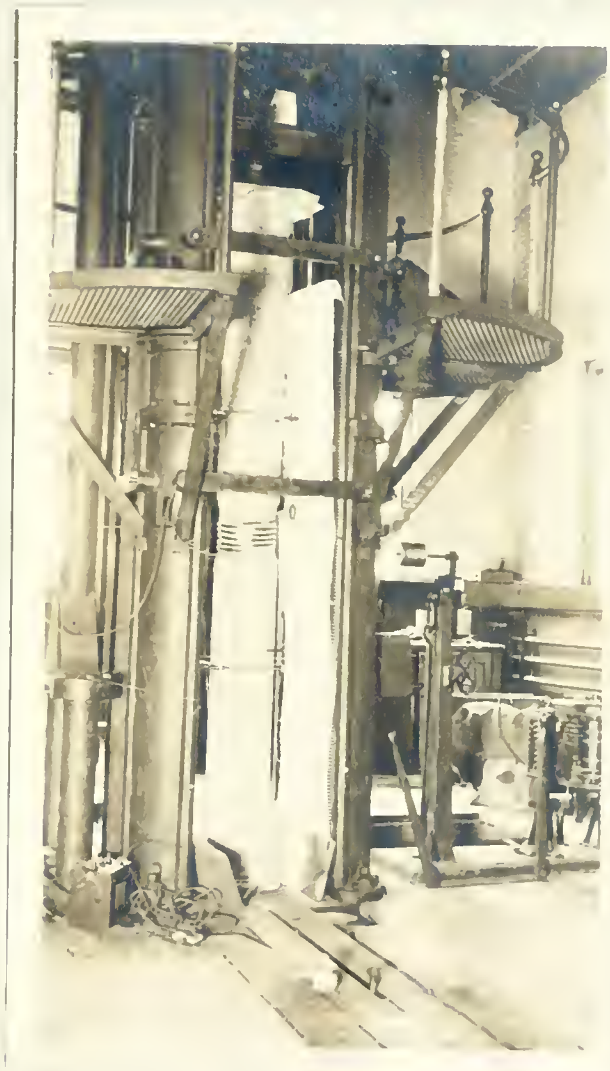

Fig. 5